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Tree Survival and Insect Activity in Partially Scorched Ponderosa Pine in the Cerro Grande Wildfire, New Mexico

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David A. Conklin and Terrence J. Rogers



Cover Photo: A bark beetle outbreak in 2002 increased tree mortality in areas that burned at low to moderate intensity during the Cerro Grande wildfire of 2000.
(Dan Ryerson, photo)

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the Cerro Grande Wildfire, New Mexico

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Abstract

Four rectangular plots containing a sample of 232 ponderosa pine were installed a few weeks after the May 2000 Cerro Grande (Los Alamos) wildfire in an area that burned at low to moderate intensity. Sample trees had an average crown (needle) scorch of about 80 percent and most had moderate to heavy bole char. Seventy-six percent were alive in May 2003, three years after the fire. Survival varied greatly by plot, with 95 percent of the mortality occurring on two of the four plots. About 75 percent of the trees that died had some sign of bark beetle attack. Nearly all of the bark beetle activity occurred in year two and three after the fire, a period of extreme drought. About 1/3 of the live trees on these plots became infested with wood borers; on one plot, a borer/woodpecker complex increased tree mortality. Over half the trees that received 100 percent crown scorch survived the three year period.

Introduction

The Cerro Grande Wildfire burned over about 43,000 acres near Los Alamos, New Mexico in early May 2000. About 15,000 acres burned as a high intensity crown fire, while the remainder generally burned at low to moderate intensity. In late June, about six weeks after the fire, we installed a set of plots to monitor bark beetle activity in fire-damaged trees in an area burned at low to moderate intensity.

Some studies conducted in the northern Rockies have indicated that fire-damaged conifers, especially Douglas-fir, are prone to bark beetle attack (Weatherby et. al. 1994, Ryan and Amman 1996, Rasmussen, et. al. 1996, USDA Forest Service 2000). Relatively little information has been available on bark beetle activity in fire-damaged ponderosa pine in the Southwest. Large outbreaks of bark beetles have generally not been observed following recent fires in New Mexico, although at least some bark beetle activity probably does occur after most sizable fires—both prescribed fires and wildfires—in the Southwest (Conklin and Armstrong 2001, McHugh and Kolb 2003).

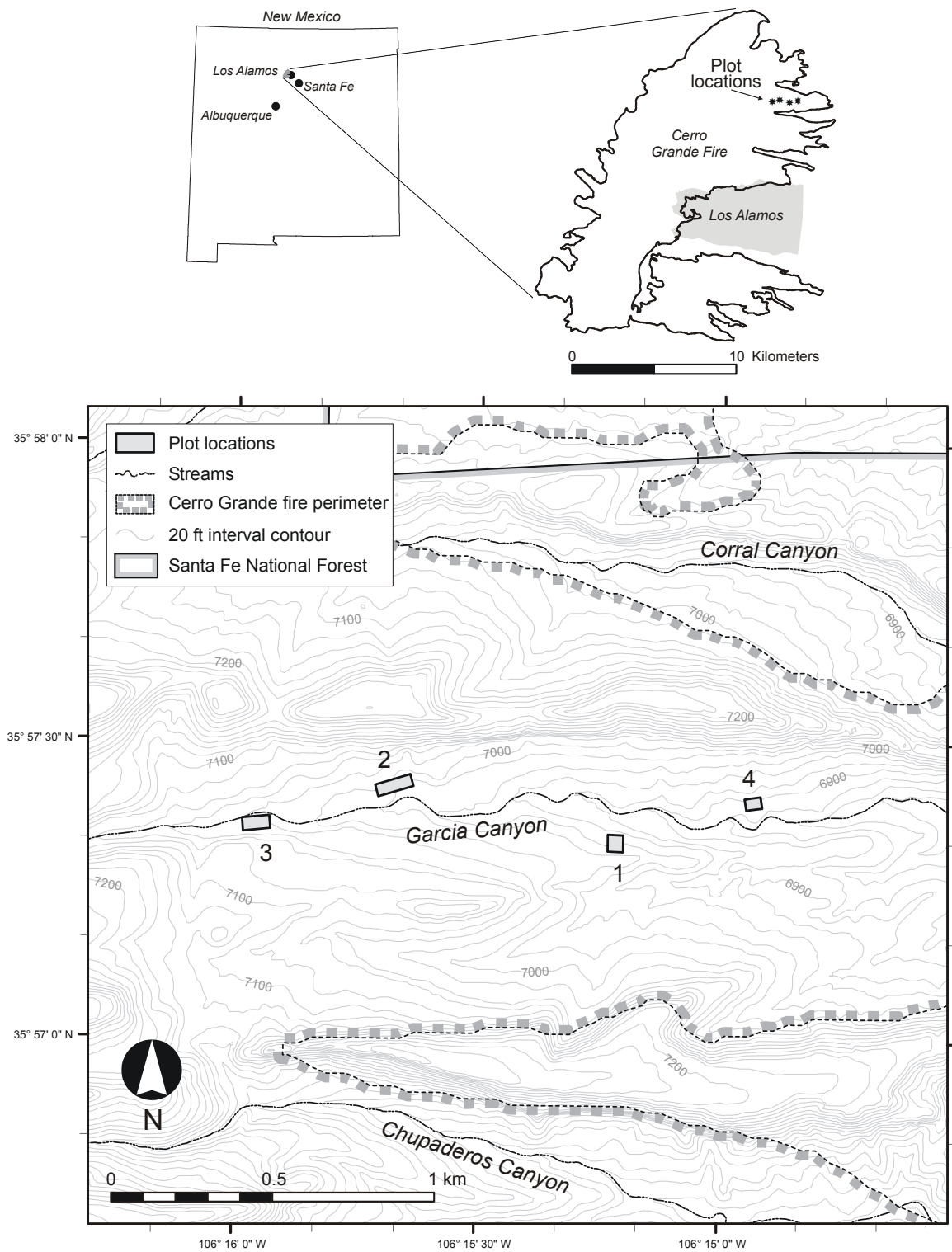
Trees killed directly by fire do not provide suitable habitat for bark beetle development. Such trees are usually easily recognized soon after a fire by a complete or nearly complete consumption of needles, a result of the fire “crowning.” Extreme cambial damage usually makes these trees unattractive to, and unsuitable for, bark beetles. Trees experiencing less intense fire often survive, at least initially, and can provide suitable bark beetle habitat. It has long been known that dead and dying trees are often entered by wood-boring insects, especially roundheaded and flatheaded beetles.

Study Area

Our plots are located in Garcia canyon, in the northern portion of the Cerro Grande fire area, about four miles northeast of Los Alamos (Figure 1). The low-elevation stringer of ponderosa pine in Garcia canyon burned at varying intensities during this large wildfire, resulting in a mosaic of partially to completely scorched areas. An intermittent stream (usually dry) lies in the bottom of Garcia Canyon. Forest Road 445 (not shown) parallels this drainage and provides access to the study area.

The forest on the south side of Garcia Canyon had been thinned in 1994 in a Forest Pest Management-funded “bark beetle prevention project.” This 137 acre treatment was a low thinning which removed one-half to two-thirds of the trees in most areas, reducing basal areas from about 120 to around 70 ft²/acre, on average. Most of the down material was promptly removed from the site by fuelwood gatherers, while a few of the larger stems were sold as vigas. Because of its proximity to archeological sites along the canyon walls, the forest on the north side of the canyon was left unthinned. Both areas were broadcast burned in 1995.

Figure 1. Cerro Grande Fire Monitoring Plots



In addition to the treatment within Garcia canyon itself, several hundred additional acres of ponderosa pine forest in nearby canyons and mesas were thinned and prescribed burned from 1994 to 1999 in what was known collectively as the Garcia Canyon Ecosystem Restoration Project. This “landscape-scale” treatment may well have moderated fire behavior within the northern portions of the Cerro Grande wildfire.

Methods

Four rectangular plots containing roughly equal sample sizes (50 to 65 trees each) were installed in easily accessible areas, about 6 weeks after the fire. The plots were intentionally located in areas having moderate to high levels of crown (needle) scorch but little to no actual crown consumption. (Areas where significant “crowning” occurred--consuming the foliage and killing the buds--would have provided little opportunity for either tree survival or bark beetle activity). Essentially all the crown scorch within our selected plot locations was a result of heat rather than direct combustion. Two plots (Plots 1 and 3) were installed in the thinned portion of Garcia Canyon, and two others (Plots 2 and 4) in the unthinned portion (Figure 1).

All ponderosa pines over 4” dbh were tagged, measured for dbh, and rated for both crown scorch and bole char. Crown scorch ratings were estimates, to the nearest 10 percent, of the proportion (length) of the live crown in which the needles were scorched. Trees were observed from several angles when estimating crown scorch. New growth from surviving buds—which was starting to become visible when these scorch ratings were made in late June--was ignored. The distribution of sample trees by scorch class is displayed in Figure 2. All of the sample trees had some crown scorch, and nearly two-third of them had ratings of 80 percent or higher.

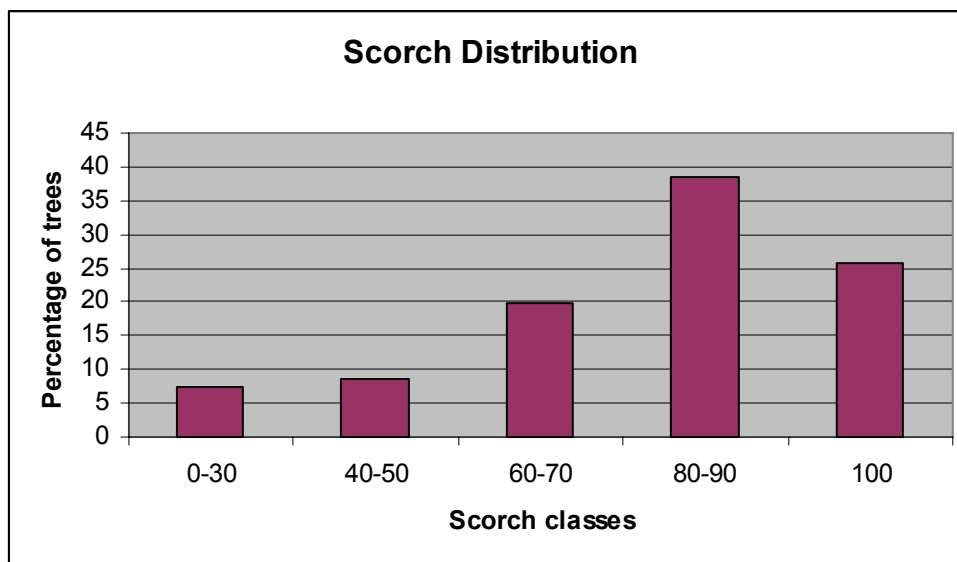


Figure 2. Proportion of sample trees, by scorch class group.

Bole char was rated simply as “light,” “moderate,” or “heavy.” Bole char was relatively uniform on our plots; most trees (86 percent) had heavily-blackened bark completely encircling the trunk and extending several feet high, and were rated “heavy.” No attempt was made to determine actual damage to the cambium, which itself would have damaged the tree and possibly even attracted bark beetles.

Initial plot attributes are summarized in Table 1 below. Most trees on these plots were about 80 years old at the time of the wildfire. Several of the larger trees on Plot 2 were 100 to 120 years old.

	Size (acres)	# Trees	Avg. dbh	BA (ft ² /ac.)	Average crown scorch	% of trees with heavy bole char
Plot 1	0.60	58	10.5	59	76%	91%
Plot 2	1.02	51	18.1	98	61%	63%
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Table 1. Plots at time of establishment.

The plots were revisited to assess insect activity and tree survival in November 2000 (six months after the fire), and in May 2001, 2002, and 2003 (one, two, and three years after the fire). We based our assessments of insect activity on external signs (boring dust, pitch tubes, etc.) until the tree was clearly dead, in order to avoid further damaging sample trees and possibly influencing our results.

Results and Discussion

Seventy-six percent (176 of the 232 sample trees) were alive in May 2003, three years after the fire. Survival varied greatly by plot, with most (95 percent) of the mortality occurring on Plots 1 and 4 (Table 2). Survival generally decreased with increasing crown scorch (Figure 3), although there was no difference in survival within the range of 40 to 90 percent scorch due to complicating factors of insect activity, tree size, and site differences. Sixty-three percent of the sample trees with 100 percent crown scorch survived. Seventy-one percent of trees with heavy bole char survived, while 100 percent (33 trees) of those with light or moderate bole char survived.

Year	Plot 1	Plot 2	Plot 3	Plot 4	Total
One	6	1	0	1	8
Two	14	0	0	6	20
Three	9	1	1	17	28
Total	29 (50%)	2 (4%)	1 (2%)	24 (37%)	56 (24%)

Table 2. Number of trees that died on each plot, by year, with percent mortality over three -year period in ().

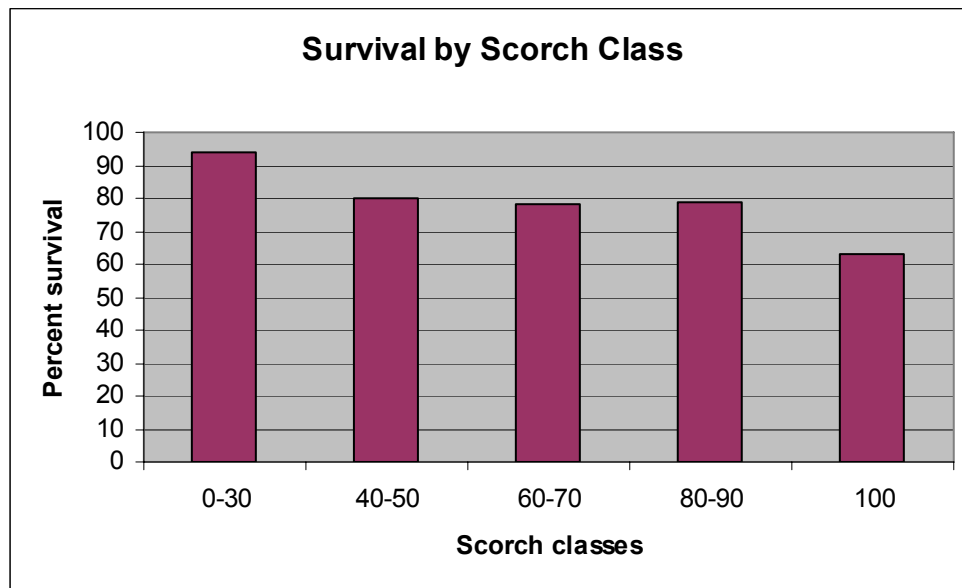


Figure 3. Proportion of sample trees surviving, by scorch class group.

Somewhat surprisingly, only eight sample trees died in the first year after the fire. Twenty trees died in year two, and 28 in year three. Most of the mortality the first two years after the fire was on Plot 1, while in year three the greatest proportion occurred on on Plot 4 (Table 2).

Insect activity

About 75 percent of the trees that died in the three years following the fire had some sign of bark beetle attack—either *Ips* sp. and/or Western pine beetle (*Dendroctonus brevicornis*). The remaining mortality was attributed to either fire damage alone or woodpeckering (see next paragraph). Nearly all of this bark beetle activity occurred in years two and three (2001 and 2002) following the fire, with about two-thirds of it in year three (Cover Photo). Several trees were attacked by red turpentine beetle the first year

after the fire; however, these survived, except for three that were heavily damaged by woodpeckering.

Surprising to us, about one-third of the live trees on these plots became infested with wood borers (Cerambycid and/or Buprestid beetles). Borer activity was most pronounced on Plot 1, where at least 32 trees (55 percent) became infested and were subsequently damaged by woodpeckers feeding on these insects.¹ This “peckering” (holes and bark sloughing) (Figure 4) appeared to have increased mortality significantly on this plot, as only 11 of these 32 trees survived. Several of the peckered trees were subsequently attacked by bark beetles, helping to assure their death. (The condition of the bark on a few of these trees made it difficult to determine whether or not they had been attacked by bark beetles). Most of the borer-infested trees on the other plots survived the three-year



period; the extent of damage to the wood in these living trees is unknown. Additional borer activity has undoubtedly occurred in dead trees—those killed by bark beetles or by the fire itself—but we have not quantified this activity. Wood borer activity in surviving, fire-damaged trees has been little documented and may warrant further study.

Figure 4. “Peckering” on scorched trees

The relatively high level of bark beetle activity that occurred the third year after the fire seemed more a result of the extreme drought in 2002 than fire damage. Under more favorable moisture conditions, it is very likely that many of the trees that died in year three would have survived. Mortality of scorched ponderosa pine has usually declined considerably in the third year after fires (Conklin and Armstrong 2001, McHugh and Kolb 2003). Nevertheless, there are indications that fire damage was a still significant factor in year three of the current study. All of the trees that were attacked by bark beetles in year three had heavy bole char, while no trees with light or moderate bole char ratings were attacked.

Precipitation records for nearby Los Alamos (<http://www.wrcc.dri.edu>) indicate significant deficits each year of the three year period, with the greatest deficit in 2002. On a percentage basis, the annual deficits are as follows: 2000: -25%, 2001: -21%, 2002: -36%. These deficit figures are based on averages since 1942. Note that in 2000, the year of the fire, the bulk of the deficit occurred prior to the May fire; the period after the fire was actually close to normal.

¹ Some wood borer activity was detected when the plots were initially set up, six weeks after the fire. At that time we had observed some fine-textured, reddish dust in bark crevasses on five trees, all on Plot 1. We initially assumed that these trees had been attacked by *Ips* bark beetles, thinking that their weakened condition had precluded the formation of pitch tubes. By November 2000 (six months after the fire), many more trees had this reddish dust, and several of them had been “peckered.” Additional peckering was evident by May 2001. By then, given that most of these trees were still green, and with the lack of pitch tubes, we realized that the reddish dust was a result of borer larvae rather than *Ips*.

Other factors affecting tree survival

Overall, there was little difference in bark beetle activity and tree mortality between the thinned areas (sampled on Plots 1 and 3) and the unthinned area (sampled on Plots 2 and 4). However, the largest seasonal outbreak did occur on unthinned Plot 4, which had the highest basal area ($>130 \text{ ft}^2$).

Survival within this study area generally increased with increasing tree size. Plots 1 and 4, where most of the mortality occurred, had smaller average dbh's than the other two plots (Tables 1 and 2). Moreover, on both Plot 1 and Plot 4, the trees that survived averaged about one inch larger in diameter than those that died. These results are consistent with Reinhardt and Ryan (1989), who estimate mortality of fire-damaged trees based on crown scorch and bark thickness (as computed from dbh). Simply stated, larger trees usually have thicker bark than smaller trees, providing greater fire resistance.

In addition to crown scorch, bole char, and tree size, it appears that site differences—elevation, aspect, and location relative to the canyon bottom (water table) greatly influenced survival rates on the four plots. Our results illustrate the complexities inherent in predicting the survival of partially scorched trees and the variation that may occur across a landscape. Some of the variation among these four plots--in order of increasing mortality--is discussed below:

Plot 3. Despite having the greatest average crown scorch (87%) and all trees having heavy bole char, this plot had the lowest mortality rate—only one tree died, a result of bark beetle attack in year three. The location of this plot in the canyon bottom, close to the water table, undoubtedly influenced survival. Fifteen of 16 trees with 100% crown scorch survived.

Plot 2. The low mortality rate (two trees) on this plot can be attributed to less severe scorch than on the other plots and the larger average tree size ($> 18''$ dbh). Its location on a bench several feet above the water table is probably not as favorable as Plot 3; nevertheless, 10 of 11 trees with 100% crown scorch survived. Our initial speculation that the relatively large, fire-damaged trees on this plot might be attractive to western pine beetle did not materialize.

The fact that Plots 2 and 3 are located further up the canyon and at slightly higher elevation than Plots 1 and 4 is another factor that cannot be discounted. The higher elevation plots probably received somewhat more precipitation over the three-year period than the lower elevation plots.

Plot 4. As of May 2002, two years after the fire, mortality was fairly low on this plot: only 7 of 65 trees (11 percent). However, at that time, the entire plot--located on a south-facing slope--appeared off-color and severely stressed. Seventeen trees were attacked and killed by bark beetles over the next twelve months (Cover Photo). Nine of 16 trees with 100% crown scorch survived the three-year period.

Plot 1. The overall impression is that this plot suffered high mortality (50 percent) because the smaller, relatively thin-barked trees were more severely damaged by bole char, and possibly root damage. Cambial damage most likely lead to the wood borer/woodpecker complex which contributed to much of the mortality. Moderate levels of bark beetle activity in years two and three helped “finish off” several of these damaged trees. The location of this plot--relatively high on the slope, where soils were thinner—probably contributed to the high mortality rate. Four of 17 trees with 100% crown scorch survived.

Survival of severely scorched trees

Other studies have reported remarkable recovery of heavily scorched ponderosa pine (Dieterich 1979, Harrington 1987). In this study, the survival rate among trees with 100% crown scorch ratings--63 percent-- was higher than we have reported in several prescribe-burned areas, where it has usually ranged from 15 to 30 percent (Conklin and Armstrong 2001; our unpublished data). Several factors account for this difference. One is that on most of our prescribed fire plots (but not the Garcia Canyon plots), some trees with 100% scorch ratings experienced *crown consumption* and were killed directly by fire. Another factor is that our prescribed fire plots were in dwarf mistletoe-infected stands, while this disease is absent in Garcia Canyon. Dwarf mistletoe infection can increase the mortality rate among heavily scorched trees (Harrington and Hawksworth 1990, Conklin and Armstrong 2001). An additional factor, discussed previously, is that the location of several sample trees in the canyon bottom contributed to the overall high survival rate on the Garcia Canyon plots.



Figure 5. Recovery of trees with 100% crown scorch. Left: Photo taken November 2000, six month after fire, after flush of new growth. Right: Photo taken May 2003, three years after fire. (Note that angle of photos is slightly different.)

Conclusions

The overall high survival rate (76 percent) among these (mostly) heavily scorched trees is all the more notable, given the prolonged drought during this period. However, if the drought continues, as it has through the first half of 2003, additional bark beetle activity and tree mortality is likely on these plots. The Los Alamos area experienced some of the highest levels of bark beetle activity in ponderosa pine in New Mexico in 2002. Results from these plots indicate that although drought has been the overriding factor in this outbreak, the partially-scorched trees from the Cerro Grande wildfire have at least contributed toward the build-up in beetle populations. The magnitude and duration of this outbreak will largely be determined by the extent and severity of the drought.

Acknowledgements

Appreciation is expressed to Dan Ryerson, Forest Health Protection, for help in data analyses, for developing Figure 1, and for providing other timely assistance during production of this report.

Literature Cited

- Conklin, D.A.; Armstrong, W.A. 2001. Effects of three prescribed fires on dwarf mistletoe infection in southwestern ponderosa pine. USDA Forest Service, R3-01-02. 17 p.
- Dieterich, J.H. 1979. Recovery potential of fire-damaged southwestern ponderosa pine. USDA Forest Service, Research Note RM-379. 8 p.
- Harrington, M.G. 1987. Ponderosa pine mortality from spring, summer, and fall crown scorching. *Western Journal of Applied Forestry* 2(1): 14-16.
- Harrington, M.G.; Hawksworth, F.G. 1990. Interactions of fire and dwarf mistletoe on mortality of southwestern ponderosa pine. In Krammes, J.S., tech coord. Effects of fire in management of southwestern natural resources: Proceedings of Symposium. Gen. Tech. Rep. RM-191. USDA Forest Service: 234-240.
- McHugh, C.W.; Kolb, T.E. 2003. Ponderosa pine mortality following fire in northern Arizona. *International Journal of Wildland Fire*, 12: 7-22.
- Rasmussen, L.A.; Amman, G.D.; Vandygriff, J.C.; Oakes, R.D.; Munson, A.S.; Gibson, K.E. 1996. Bark beetle and wood borer infestation in the greater Yellowstone area during four postfire years. USDA Forest Service, Research Paper INT-RP-487. 9p.
- Reinhardt, E.D.; Ryan, K.C. 1989. Estimating tree mortality resulting from prescribed fire. In: Baumgartner et. al. (eds.). Prescribed fire in the Intermountain Region: Symposium Proceedings, Washington State University: 41-44.
- Ryan, K.C.; Amman, G.D. 1996. Bark beetle activity and delayed tree mortality in the greater Yellowstone area following the 1988 fires. In Keane et. al. (eds.). Ecological implications of fire in the greater Yellowstone: Symposium Proceedings, Int. Assoc. Wildland Fire, Fairfield, WA: 151-158.
- Weatherby, J.C.; Mocettini, P.; Gardner, B.R. 1994. Biological evaluation of tree survivorship within the Loman Fire boundary, 1989-1993. USDA Forest Service, R4-94-06. 10 p.
- USDA Forest Service. 2000. Survivability and deterioration of fire-injured trees in the northern Rocky Mountains: a review of the literature. Forest Health Protection, Northern Region, Missoula Field Office. Report 2000-13.

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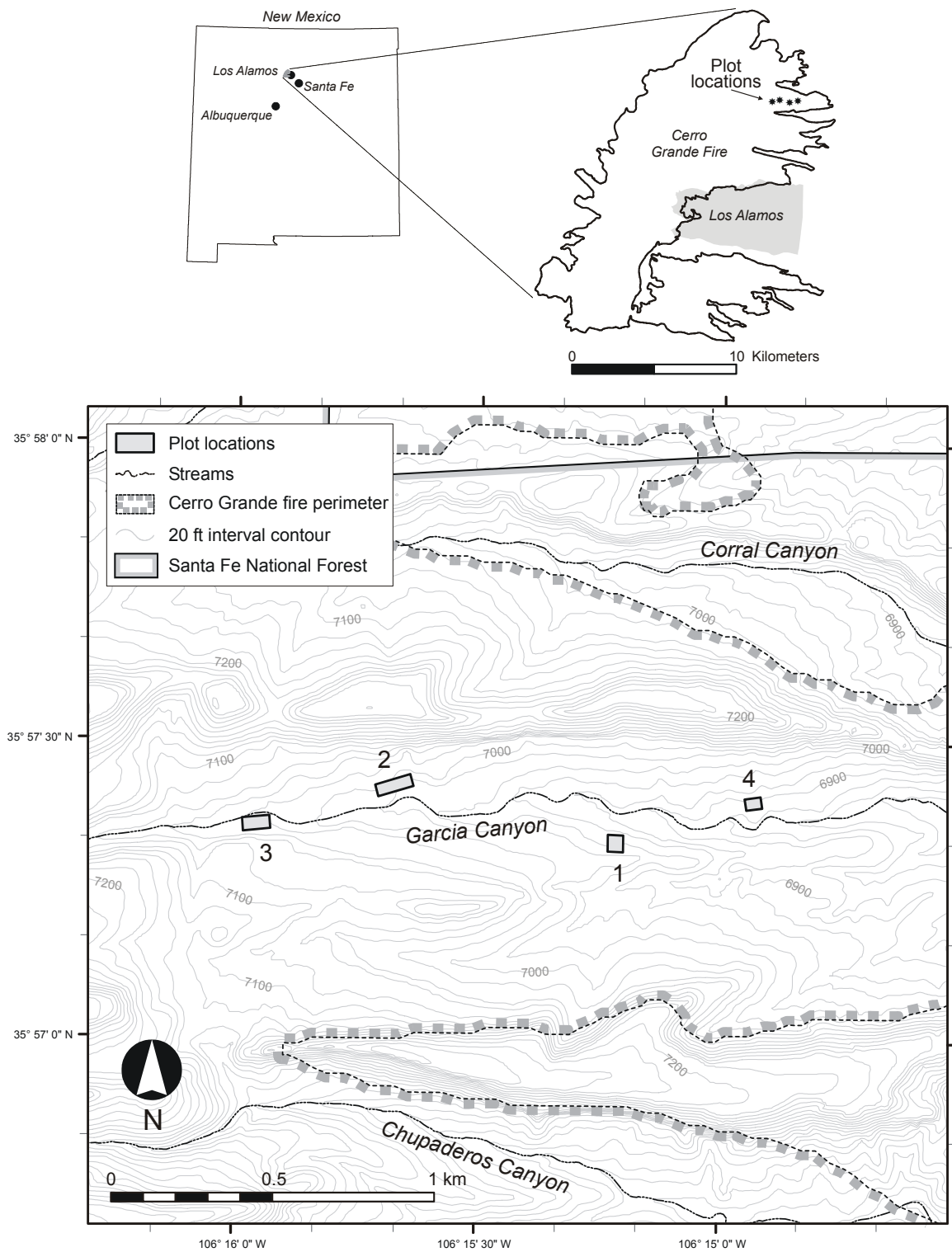
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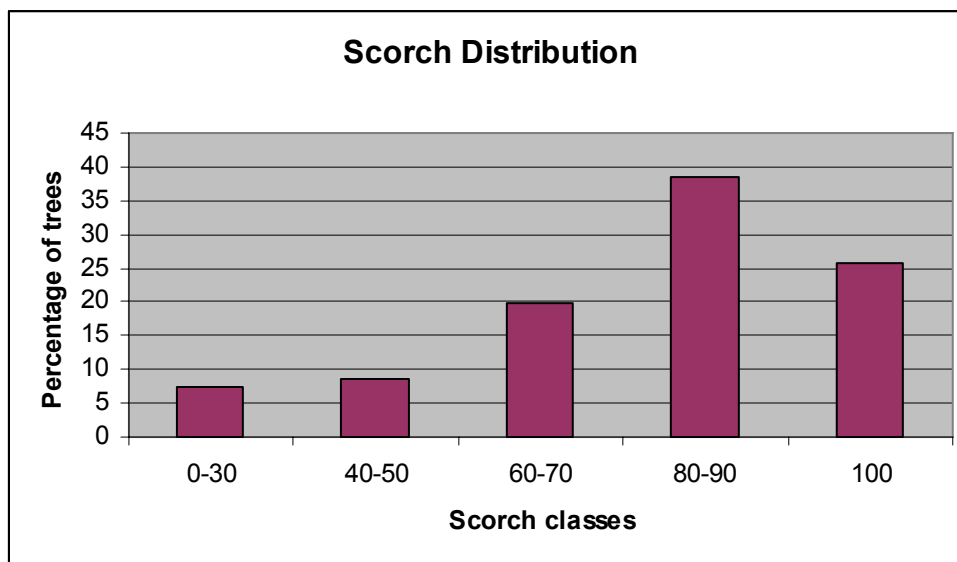


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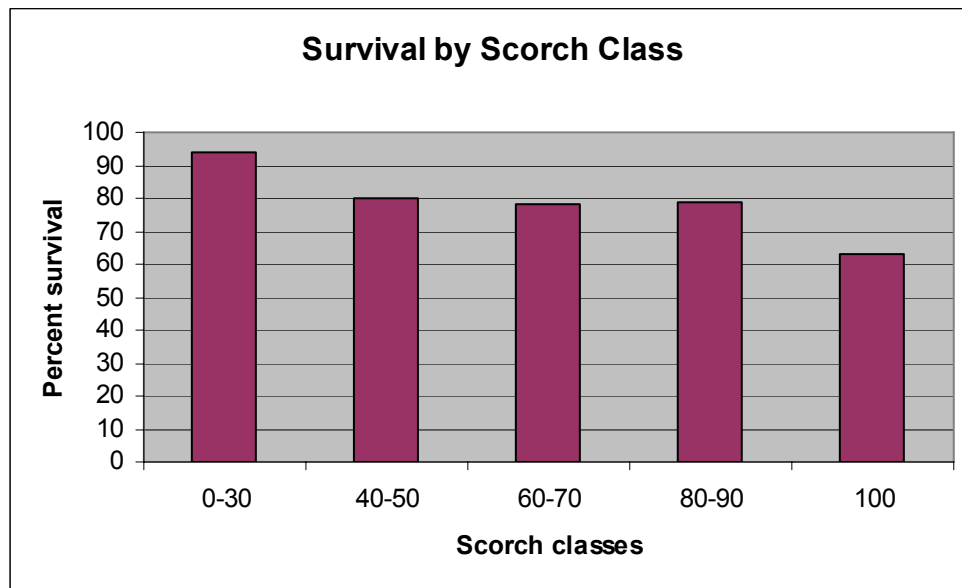


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Overall, there was little difference in bark beetle activity and tree mortality between the thinned areas (sampled on Plots 1 and 3) and the unthinned area (sampled on Plots 2 and 4). However, the largest seasonal outbreak did occur on unthinned Plot 4, which had the highest basal area ($>130 \text{ ft}^2$).

Survival within this study area generally increased with increasing tree size. Plots 1 and 4, where most of the mortality occurred, had smaller average dbh's than the other two plots (Tables 1 and 2). Moreover, on both Plot 1 and Plot 4, the trees that survived averaged about one inch larger in diameter than those that died. These results are consistent with Reinhardt and Ryan (1989), who estimate mortality of fire-damaged trees based on crown scorch and bark thickness (as computed from dbh). Simply stated, larger trees usually have thicker bark than smaller trees, providing greater fire resistance.

In addition to crown scorch, bole char, and tree size, it appears that site differences—elevation, aspect, and location relative to the canyon bottom (water table) greatly influenced survival rates on the four plots. Our results illustrate the complexities inherent in predicting the survival of partially scorched trees and the variation that may occur across a landscape. Some of the variation among these four plots--in order of increasing mortality--is discussed below:

Plot 3. Despite having the greatest average crown scorch (87%) and all trees having heavy bole char, this plot had the lowest mortality rate—only one tree died, a result of bark beetle attack in year three. The location of this plot in the canyon bottom, close to the water table, undoubtedly influenced survival. Fifteen of 16 trees with 100% crown scorch survived.

Plot 2. The low mortality rate (two trees) on this plot can be attributed to less severe scorch than on the other plots and the larger average tree size ($> 18''$ dbh). Its location on a bench several feet above the water table is probably not as favorable as Plot 3; nevertheless, 10 of 11 trees with 100% crown scorch survived. Our initial speculation that the relatively large, fire-damaged trees on this plot might be attractive to western pine beetle did not materialize.

The fact that Plots 2 and 3 are located further up the canyon and at slightly higher elevation than Plots 1 and 4 is another factor that cannot be discounted. The higher elevation plots probably received somewhat more precipitation over the three-year period than the lower elevation plots.

Plot 4. As of May 2002, two years after the fire, mortality was fairly low on this plot: only 7 of 65 trees (11 percent). However, at that time, the entire plot--located on a south-facing slope--appeared off-color and severely stressed. Seventeen trees were attacked and killed by bark beetles over the next twelve months (Cover Photo). Nine of 16 trees with 100% crown scorch survived the three-year period.

Plot 1. The overall impression is that this plot suffered high mortality (50 percent) because the smaller, relatively thin-barked trees were more severely damaged by bole char, and possibly root damage. Cambial damage most likely lead to the wood borer/woodpecker complex which contributed to much of the mortality. Moderate levels of bark beetle activity in years two and three helped “finish off” several of these damaged trees. The location of this plot--relatively high on the slope, where soils were thinner—probably contributed to the high mortality rate. Four of 17 trees with 100% crown scorch survived.

Survival of severely scorched trees

Other studies have reported remarkable recovery of heavily scorched ponderosa pine (Dieterich 1979, Harrington 1987). In this study, the survival rate among trees with 100% crown scorch ratings--63 percent-- was higher than we have reported in several prescribe-burned areas, where it has usually ranged from 15 to 30 percent (Conklin and Armstrong 2001; our unpublished data). Several factors account for this difference. One is that on most of our prescribed fire plots (but not the Garcia Canyon plots), some trees with 100% scorch ratings experienced *crown consumption* and were killed directly by fire. Another factor is that our prescribed fire plots were in dwarf mistletoe-infected stands, while this disease is absent in Garcia Canyon. Dwarf mistletoe infection can increase the mortality rate among heavily scorched trees (Harrington and Hawksworth 1990, Conklin and Armstrong 2001). An additional factor, discussed previously, is that the location of several sample trees in the canyon bottom contributed to the overall high survival rate on the Garcia Canyon plots.



Figure 5. Recovery of trees with 100% crown scorch. Left: Photo taken November 2000, six month after fire, after flush of new growth. Right: Photo taken May 2003, three years after fire. (Note that angle of photos is slightly different.)

Conclusions

The overall high survival rate (76 percent) among these (mostly) heavily scorched trees is all the more notable, given the prolonged drought during this period. However, if the drought continues, as it has through the first half of 2003, additional bark beetle activity and tree mortality is likely on these plots. The Los Alamos area experienced some of the highest levels of bark beetle activity in ponderosa pine in New Mexico in 2002. Results from these plots indicate that although drought has been the overriding factor in this outbreak, the partially-scorched trees from the Cerro Grande wildfire have at least contributed toward the build-up in beetle populations. The magnitude and duration of this outbreak will largely be determined by the extent and severity of the drought.

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Literature Cited

- Conklin, D.A.; Armstrong, W.A. 2001. Effects of three prescribed fires on dwarf mistletoe infection in southwestern ponderosa pine. USDA Forest Service, R3-01-02. 17 p.
- Dieterich, J.H. 1979. Recovery potential of fire-damaged southwestern ponderosa pine. USDA Forest Service, Research Note RM-379. 8 p.
- Harrington, M.G. 1987. Ponderosa pine mortality from spring, summer, and fall crown scorching. *Western Journal of Applied Forestry* 2(1): 14-16.
- Harrington, M.G.; Hawksworth, F.G. 1990. Interactions of fire and dwarf mistletoe on mortality of southwestern ponderosa pine. In Krammes, J.S., tech coord. Effects of fire in management of southwestern natural resources: Proceedings of Symposium. Gen. Tech. Rep. RM-191. USDA Forest Service: 234-240.
- McHugh, C.W.; Kolb, T.E. 2003. Ponderosa pine mortality following fire in northern Arizona. *International Journal of Wildland Fire*, 12: 7-22.
- Rasmussen, L.A.; Amman, G.D.; Vandygriff, J.C.; Oakes, R.D.; Munson, A.S.; Gibson, K.E. 1996. Bark beetle and wood borer infestation in the greater Yellowstone area during four postfire years. USDA Forest Service, Research Paper INT-RP-487. 9p.
- Reinhardt, E.D.; Ryan, K.C. 1989. Estimating tree mortality resulting from prescribed fire. In: Baumgartner et. al. (eds.). Prescribed fire in the Intermountain Region: Symposium Proceedings, Washington State University: 41-44.
- Ryan, K.C.; Amman, G.D. 1996. Bark beetle activity and delayed tree mortality in the greater Yellowstone area following the 1988 fires. In Keane et. al. (eds.). Ecological implications of fire in the greater Yellowstone: Symposium Proceedings, Int. Assoc. Wildland Fire, Fairfield, WA: 151-158.
- Weatherby, J.C.; Mocettini, P.; Gardner, B.R. 1994. Biological evaluation of tree survivorship within the Loman Fire boundary, 1989-1993. USDA Forest Service, R4-94-06. 10 p.
- USDA Forest Service. 2000. Survivability and deterioration of fire-injured trees in the northern Rocky Mountains: a review of the literature. Forest Health Protection, Northern Region, Missoula Field Office. Report 2000-13.